MULTIMEDIA UNIVERSITY

STUDENT ID NO

MULTIMEDIA UNIVERSITY

FINAL EXAMINATION

TRIMESTER 1, 2019/2020

ETM4146 – DIGITAL WIRELESS COMMUNICATIONS

(TE)

14 OCTOBER 2019

2:30 P.M – 4:30 P.M.

(2 Hours)

INSTRUCTIONS TO STUDENT

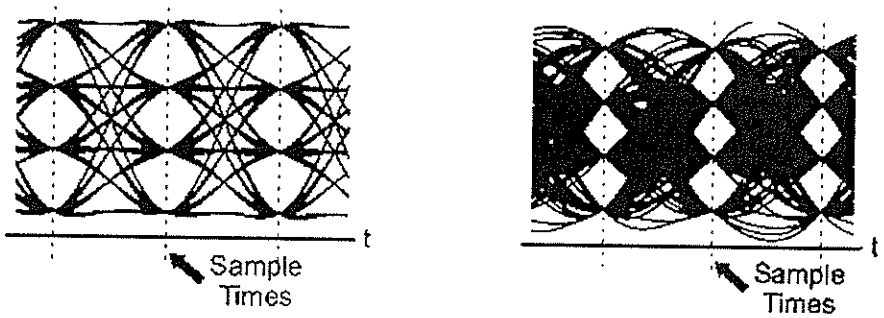
1. This exam paper consists of **5 pages** with **4 questions**.

2. Attempt **ALL questions**. All questions have equal weightage and the breakdown of marks within each question is given.

3. Please write all your answers in the answer booklet provided. Show all relevant steps to obtain maximum marks

Question 1

a) Figure 1.1 shows the eye diagrams for the I-component of the 16-QAM signal before and after the roll-off factor of the root raised cosine pulse shaping is varied.



(a) Before (b) After

Figure 1.1

i) Based on this observation, comment on the value of roll-off factor before and after the change. Justify your answer.

[5 marks]

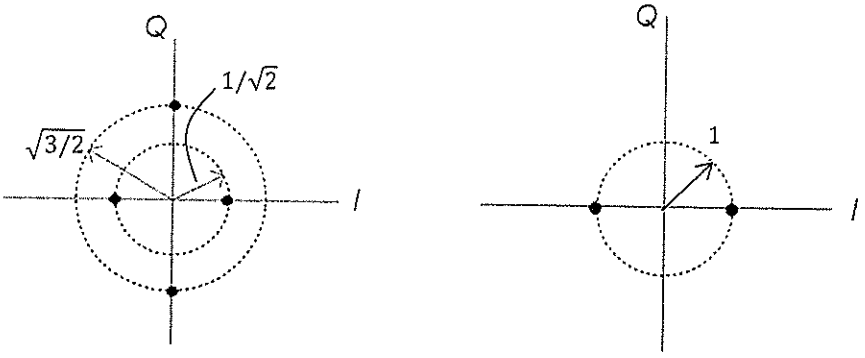
ii) Explain what impairment is being added or removed from the received signal as the roll-off factor is varied (from a to b).

[4 marks]

b) What is the relation between the excess bandwidth of the root raised cosine pulse and inter-symbol interference (ISI) (i.e. does ISI increase or decrease with increasing excess bandwidth, and why)?

[5 marks]

c) Figure 1.2 shows the constellation diagrams for 4-QAM and BPSK modulations.



(a) 4-QAM (b) BPSK

Figure 1.2

Discuss the advantages and disadvantages of the two modulation methods above in terms of average power, data rate and symbol error rate performance.

[11 marks]

Continued...

Question 2

Suppose the baseband received signal at the n-th sampling instant is given by

$$y[n] = s_i[n] + z[n]$$

where s_i is the transmitted data symbol, and z is the zero-mean white Gaussian noise with variance σ^2. Maximum likelihood (ML) detector is used in the receiver for recovering the transmitted symbols.

a) For each of the constellation diagrams in Figure 1.2, draw the decision regions (Voronoi regions) of the constellations for ML symbol detection.

[7 marks]

b) Given that the pairwise error probability is

$$P(s_i \rightarrow s_j) = Q\left(\frac{d_{ij}}{2\sigma}\right)$$

where $P(s_i \rightarrow s_j)$ denotes the probability that symbol s_i is mistaken for symbol s_j that has Euclidean distance d_{ij} from s_i, and $Q(x) = \frac{1}{\sqrt{2\pi}}\int_x^\infty e^{-u^2/2}du$. Derive the exact average symbol error probability for the BPSK modulation (as given in Figure 1.2) in terms of the Q-function, $Q(x)$.

[6 marks]

c) Derive the union bound for the average probability of symbol error for the 4-QAM modulation (as given in Figure 1.2).

[12 marks]

Continued...

Question 3

Figure 3.1 below shows the block diagram of an orthogonal frequency division multiplexing (OFDM) receiver.

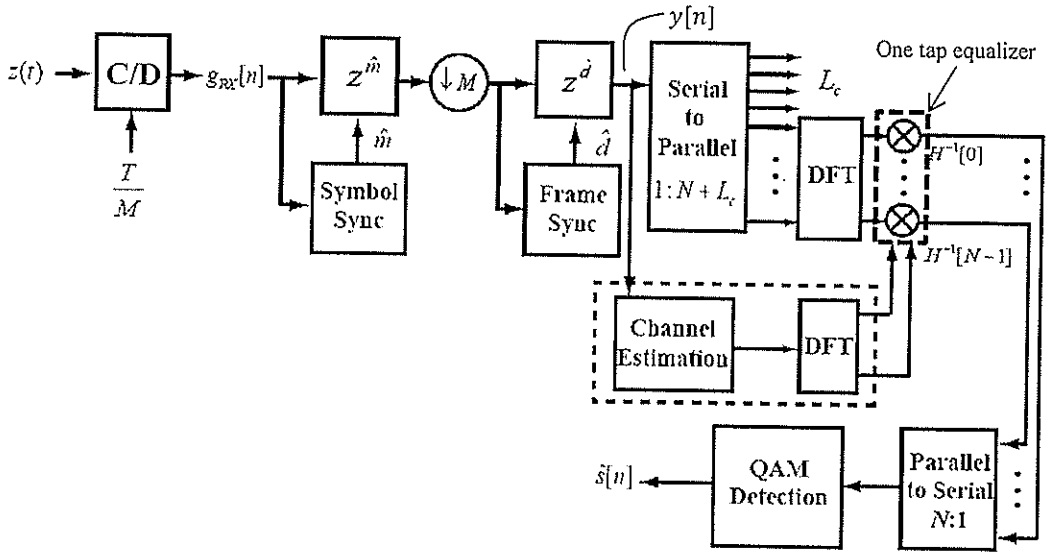


Figure 3.1

a) The receiver in Figure 3.1 employs the time-domain channel estimation approach to estimate the channel frequency response $H[k]$ $(k = 0,1, \ldots N-1)$ that is needed by the one-tap equalizer. Suppose the observed signal after matched filtering and downsampling is given by

$$y[n] = \sum_{l=0}^{L} h[l]w[n-l] + v[n]$$

where $h[l]$ $(l = 0,1, \ldots, L)$ is the channel impulse response, $w[n]$ is the transmitted OFDM samples and $v[n]$ is the noise. If $s[n]$ is the known training symbol, describe (using proper mathematical models) how a time-domain Least Squares (LS) channel estimator works.

[10 marks]

b) Another approach for estimating the channel frequency responses $H[k]$ with training symbols is called the frequency-domain approach. If the training symbol on subcarrier k is denoted as $S[k]$, explain how a Least Squares (LS) channel estimate can be computed. Modify the block diagram in Figure 3.1 to illustrate this approach.

[5 marks]

Continued...

c) OFDM is very sensitive to carrier frequency offset (CFO). Give two possible causes of CFO in OFDM systems. Figure 3.2 below shows the two adjacent subcarriers in an OFDM spectrum:

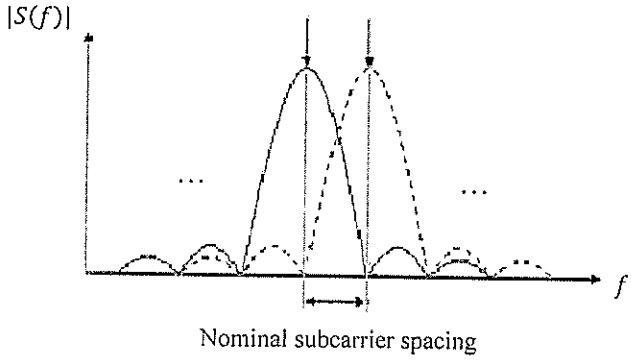


Figure 3.2

Based on Figure 3.2, draw a diagram to illustrate the two important consequences of CFO for an OFDM system.

[10 marks]

Question 4

a) Multiple-Input Multiple-Output (MIMO) communications that are used in wireless systems operate either in single-user MIMO or multi-user MIMO mode. Explain these two concepts.

[10 marks]

b) State the differences between transmit diversity and spatial multiplexing.

[4 marks]

c) Consider a deterministic multiple-input single-output (MISO) channel with additive white Gaussian noise (AWGN) in which the elements of the channel vector $\boldsymbol{h} = [h_1, h_2, \ldots, h_{N_T}]$ satisfy the conditions $|h_i|^2 = 1$, for $i = 1, 2, \ldots, N_T$.

i) Determine the capacity of this MISO channel when $\boldsymbol{h}$ is known at the receiver only.

[5 marks]

ii) How does this capacity compare with that of a single-input multiple-output (SIMO) and single-input single-output (SISO) channel?

[6 marks]

End of paper.